NOFA SUMMER CONFERENCE

The Role of Biochar in Organic Farming

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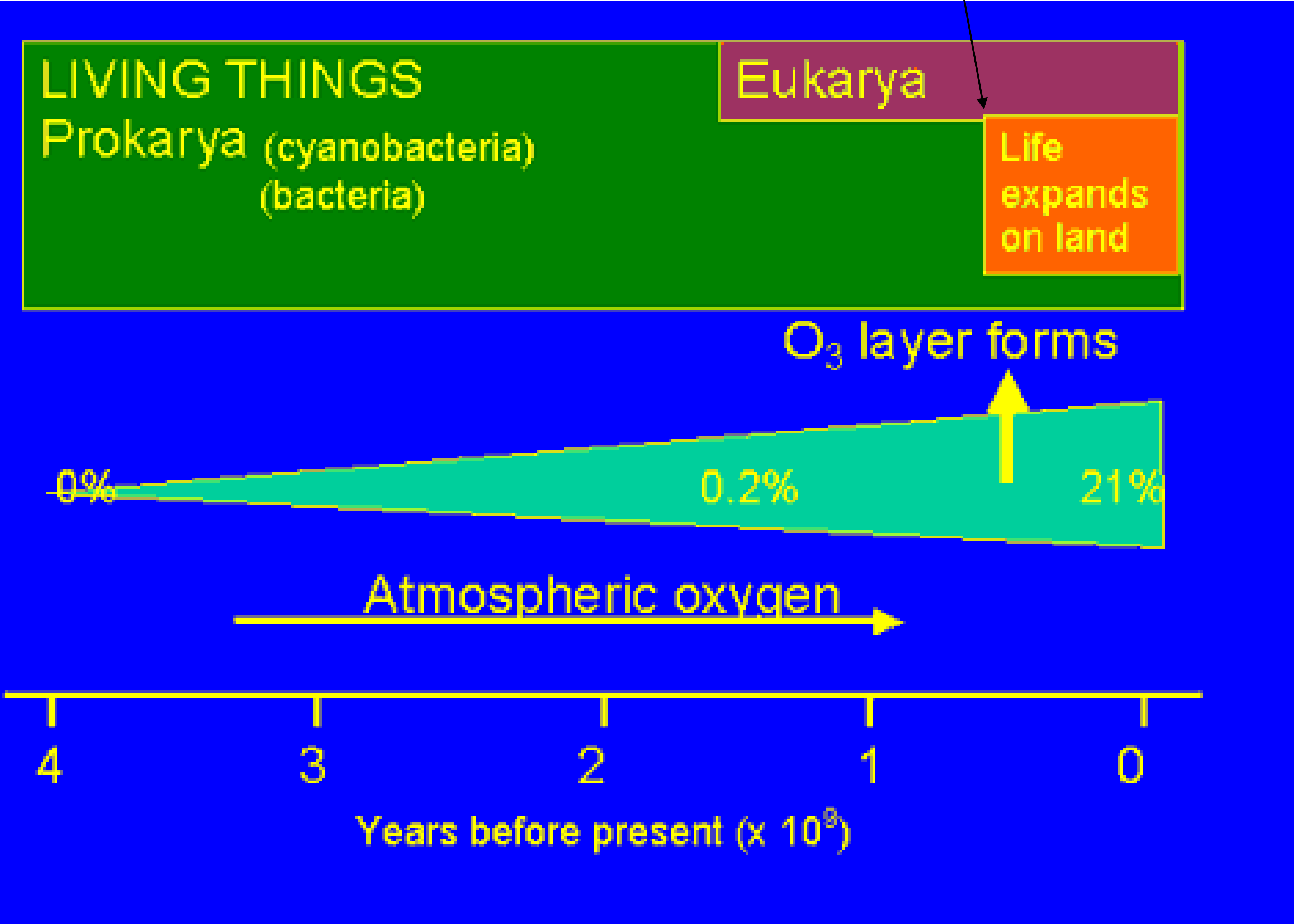
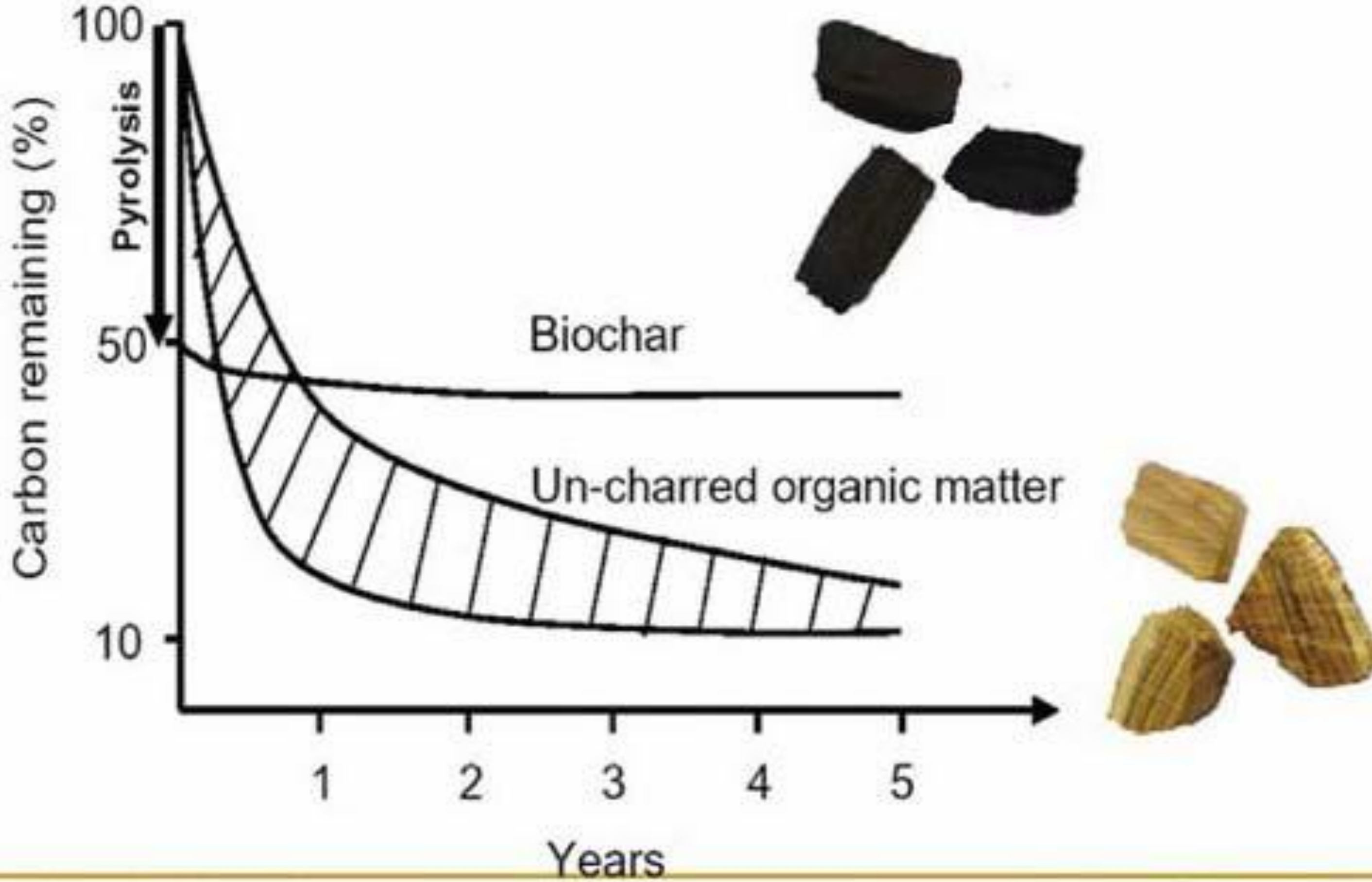
Biochar has beneficial effects when properly integrated into an organic farming system. It is a permanent soil amendment that improves the performance of the soil-crop system in multiple ways, especially moisture management and soil microbiology health. Learn:

- its properties,
- options for making or buying it, and
- methods for integrating biochar into a variety of organic growing systems.

Biochar "invented" 600 million years ago by Mother Nature

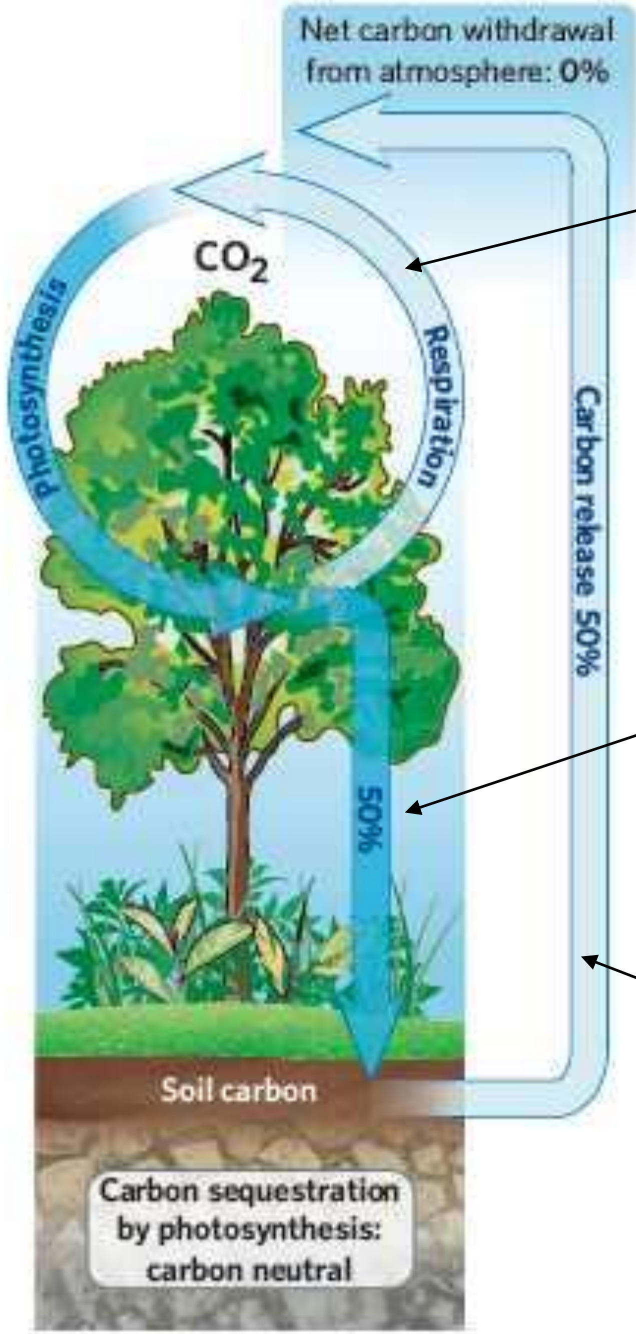


The essential stability of biochar



Lehmann et al., 2006, *Mitigation and Adaptation Strategies for Global Change* 11, 403-427

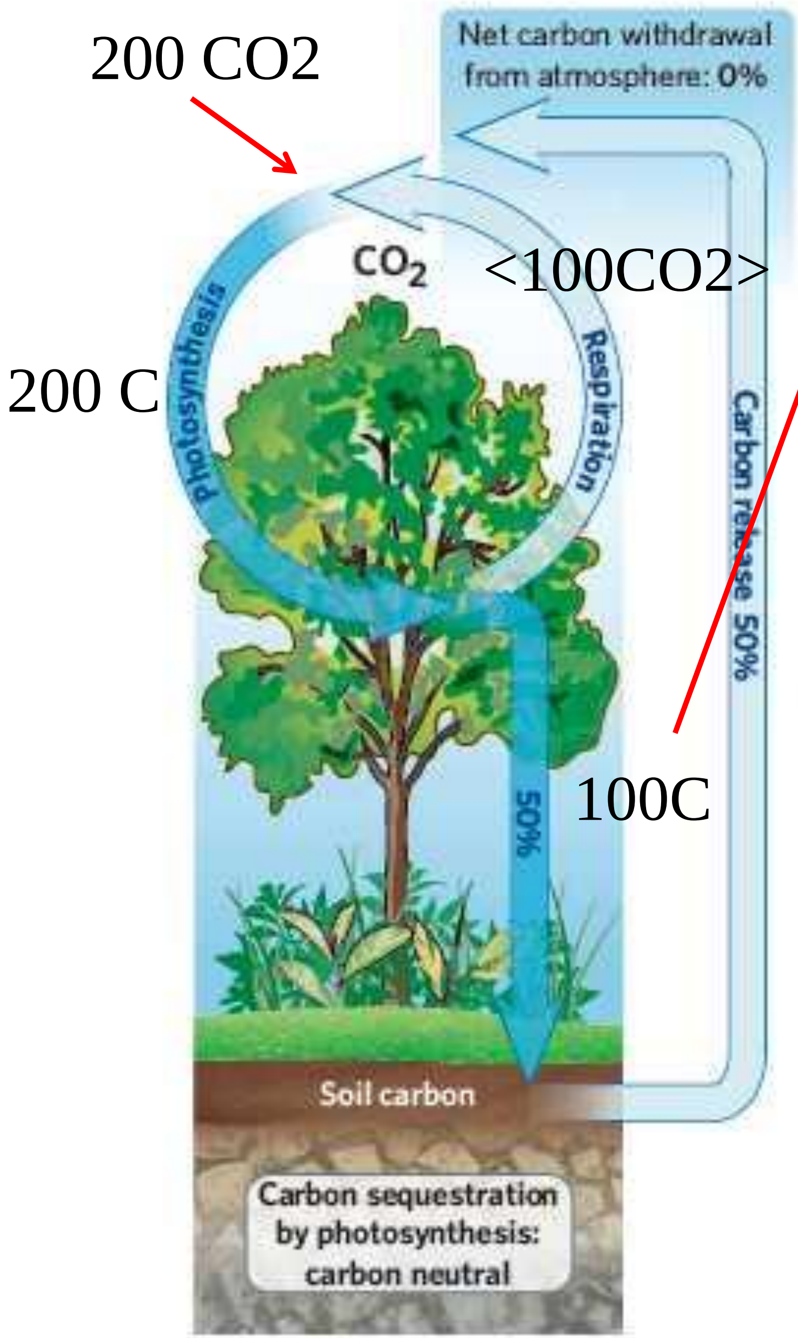
Cornell University



This is the tree as it grows. About one half of the carbon dioxide uptake results in additional carbon atoms in biomass

This is when biomass dies and becomes **detritus**: such as leaves and tree death

This is due to microbial breakdown of dead biomass – 95% in one to twenty years



Fate of Reduced or "Fixed" Carbon

- Sugars are excreted into the soil biota in exchange for plant nutrients (NPK and micro-nutrients).

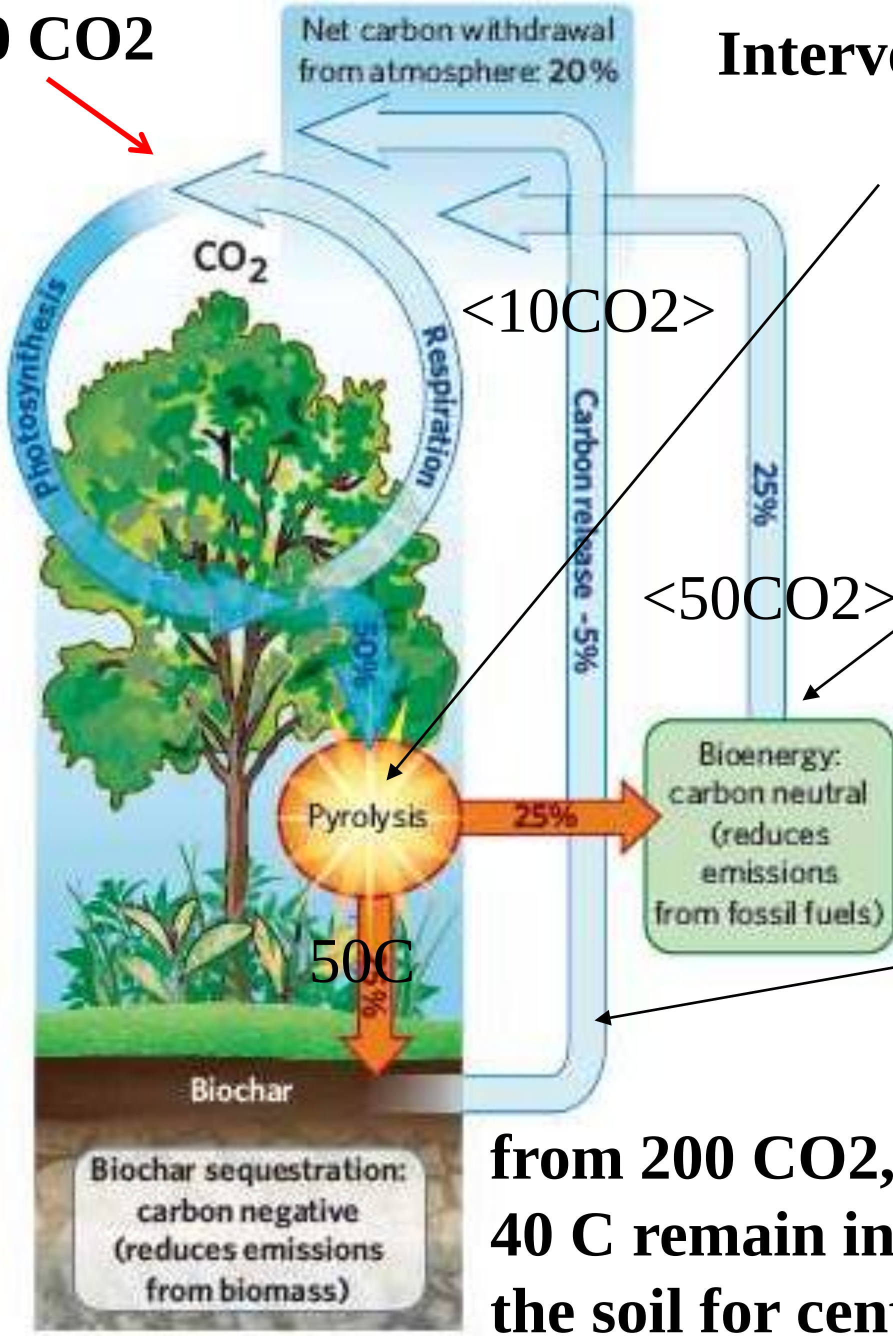
- After the plant takes care of energy requirements of procuring a balanced diet, the excess carbon is directed to seeds, biomass growth or stored as sugars for the next season.

- If NPK are available, the plant does not "waste" sugars on soil. microbes and puts that carbon into plant priorities = more plant growth

- ***Without plant sugars, soil microbes attack each other and soil carbon decreases, leading to sterile soil.***

Intervening to assist Mother Nature

200 CO2



Pyrolysis and Carbonization convert biomass into biochar: one half of the carbon atoms are released as volatiles and one half converted to biochar

The volatiles contain carbon atoms that the tree removed from the atmosphere as it grew = carbon neutral

A minority of biochar is slowly oxidized by soil microbes**; the majority is stable for hundreds to thousands of years**

from 200 CO2, 40 C remain in the soil for centuries

Principal Constituents of Biochar:

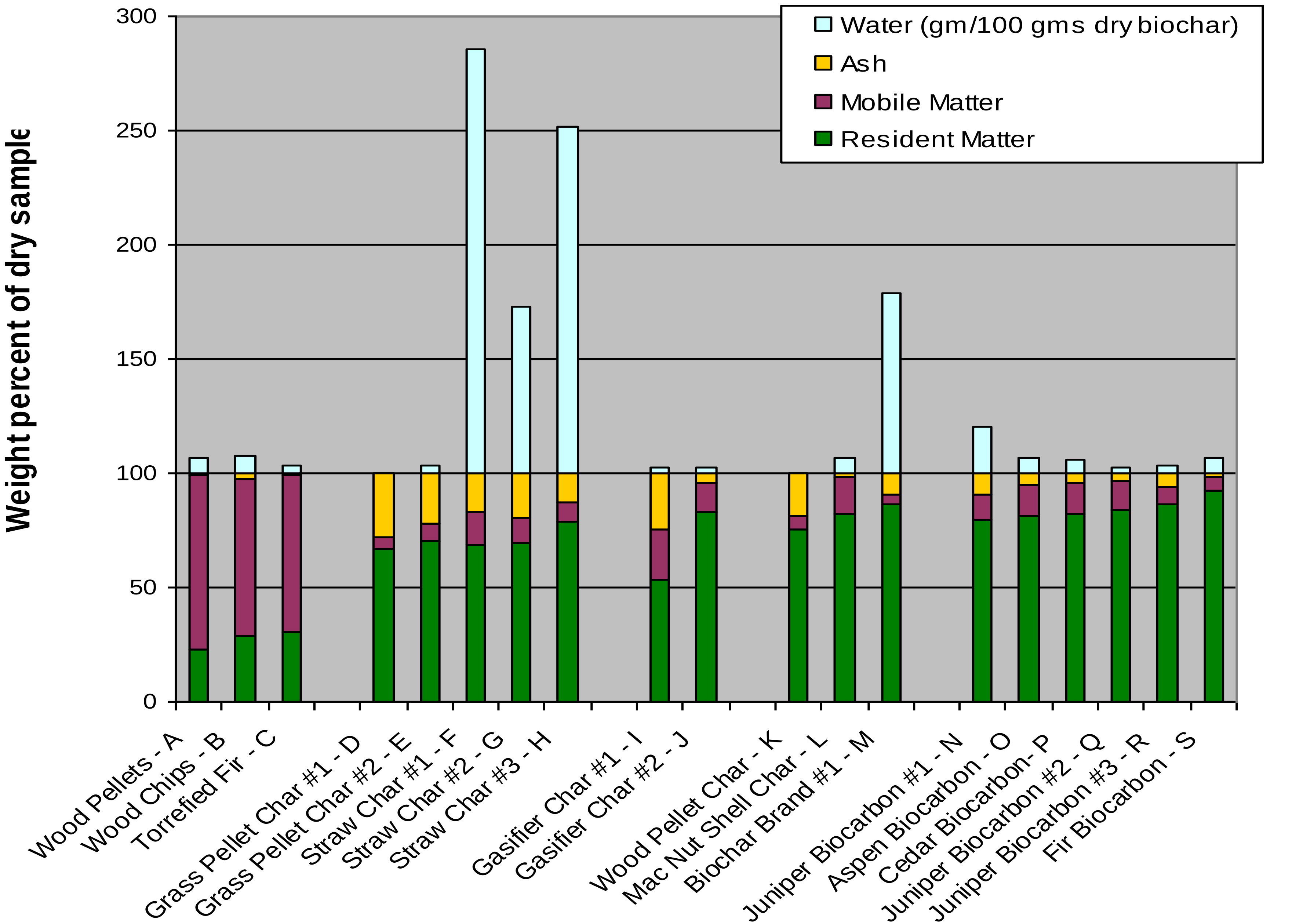
- **Moisture (as delivered)**
  - Moisture is not a bad thing, but it is not worth paying for ……
  - Moisture is added after char production, usually to cool or passivate the char
  - Moisture in the bag does not mean the char will have superior moisture retention in soil – it means moisture was added …

Principal Constituents of Biochar:

- **Ash (as delivered and from what)**
  - Converting Biomass to Char removes the moisture and much of the organic portion, but very little of the ash constituents – they accumulate to 3 to 4 times of the level present in the dry pre-carbonization biomass
  - Soluble Ash is the principal pH effect of biochar addition to soils – can act like lime
  - Ash includes Nitrogen? – depends on test
  - **Biochar does not convey plant nitrogen – but it facilitates nitrogen-fixing microbes**

Principal Constituents of Biochar:

- Moisture (as delivered)
- Ash (as delivered and from what)
- **Mobile Matter versus Resident Matter**
  - Mobile - can migrate out of the char
  - Resident - stays with the char & soil
  - Matter = Carbon and H&O portions
  - Carbon is measured for CO_2 sequestration, but plants care about soluble organics and plant nutrients available in the soil


Weight percent of dry sample
300
250
200
150
100
50
0
Water (gm/100 gms dry biochar)
Ash
Mobile Matter
Resident Matter
Wood Pellets - A
Wood Chips - B
Torrefied Fir - C
Grass Pellet Char #1 - D
Grass Pellet Char #2 - E
Straw Char #1 - F
Straw Char #2 - G
Straw Char #3 - H
Gasifier Char #1 - I
Gasifier Char #2 - J
Wood Pellet Char - K
Mac Nut Shell Char - L
Biochar Brand #1 - M
Juniper Biocarbon #1 - N
Aspen Biocarbon - O
Cedar Biocarbon- P
Juniper Biocarbon #2 - Q
Juniper Biocarbon #3 - R
Fir Biocarbon - S

Principal Constituents of Biochar:

- Moisture (as delivered)
- Ash Content (as delivered and from what)
- Mobile Matter versus Resident Matter

- **Cation Exchange Capacity**
  - **ion exchange resin-like behavior**

- **Adsorption Capacity**
  - **activated carbon (adsorption) behavior**

Pivotal Biochar properties:

Short-term Effects are due primarily to

- **Ash Content** – due to pH impact
- **Mobile Matter** – as a carbon source for soil microbes, which will compete for available nitrogen
- Mobile matter, if “sugar”, can jump-start soil biology

Long-term Effects are attributed to **only** the

- **Resident Matter** – because it
  - ***Adds Volume with high porosity to the soil***
  - ***Increases Cation Exchange Capacity***
  - ***Introduces significant Adsorption Capacity***

How does Biochar work in the Soil?

- *Biochar works in conjunction with the existing soil, crop and climate.*
- *Biochar helps "soil" go back to being soil.*

- Improved Moisture Dynamics – high & low
- Improved Nutrient Retention (N, P, K)
- Improved Microbe survival during drought and between active plant growth periods
- Improved Plant-Microbe synergisms

How does Resident Matter accomplish the following in the Soil?

- Improved Moisture Dynamics – high & low

Two different moisture regimes,

with three different mechanisms:

- – High moisture in tight soils (flooding in clays)
- – High moisture in loose soils (flooding in sand)
- – Low moisture in all soils
  - desiccating or drought conditions

How does Resident Matter accomplish the following in the Soil?

- Improved Nutrient Retention (N, P, K)

This is the CEC = Cation Exchange Capacity property

Biochar has both Cation and Anion Exchange capacity

- Exchange Capacity is due to non-graphitic organic side chains, oxidized to organic acid functionalities and organic bases due to bound nitrogen molecules

- Adsorption of Humic and Fulvic Acids also increases AEC & CEC and provides “labile” carbon inventory

How does Resident Matter accomplish the following in the Soil?

- Improved Microbe survival during drought
- Improved Plant-Microbe synergisms

Microbes need two things to survive: food and water

- If the plant has enough water, so do the bugs

- The plant feeds the right bugs to get plant nutrients

- Biochar adsorbs water and water soluble organics in micropores – and desorbs them during periods of between crops (time of no extrudates – out of a job) https://en.wikipedia.org/wiki/Characterisation_of_pore_space_in_soil

Characterization of pore space in soil

Macropore

The pores that are too large to have any significant capillary force. These pores are full of air at field capacity. **Size >75 µm.**

Mesopore

The pores filled with water at field capacity. Also known as storage pores because of the ability to store water useful to plants. **Size: 75 µm–30 µm.**

Micropore

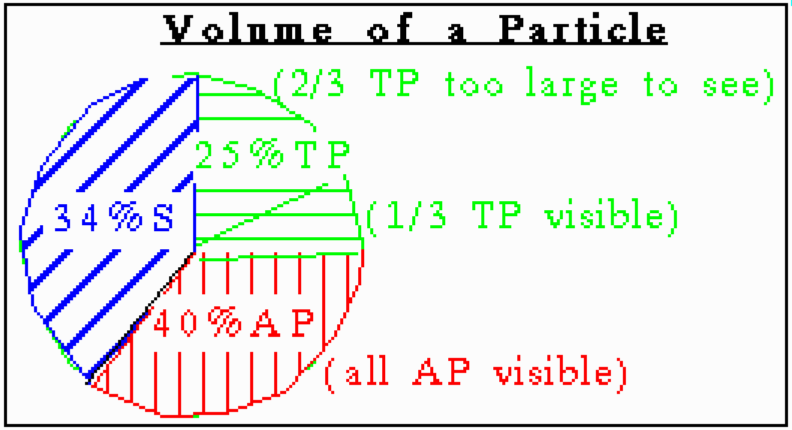
The pores that are filled with water at permanent wilting point. These pores are too small for a plant to use without great difficulty. The water held in micropores is important to the activity of microbes creating moist anaerobic conditions. **Size <30 µm.**

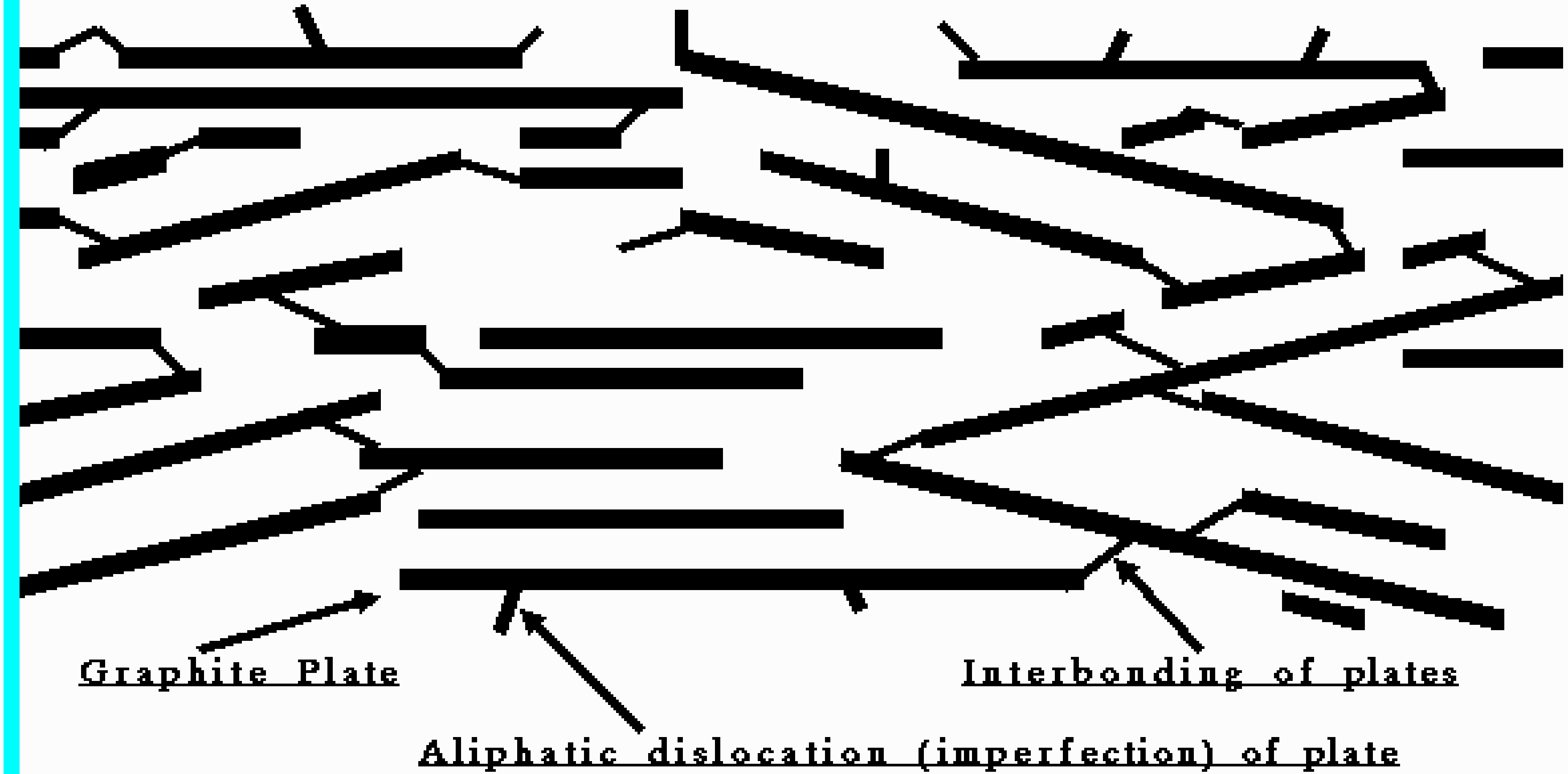
http://www.desotec.com/carbonology/activated-carbon-carbonology/activated-carbon-pores/3670/

Activated carbon pores for adsorption

Adsorption pores are the only regions within an active carbon particle with sufficient adsorption forces to **adsorb impurities**. They are the smallest pores within the particle, consisting of gaps between the graphite plates of about 1 to 5 molecular diameters in size. This can be explained by the fact that London dispersion forces are short ranged and distance sensitive.

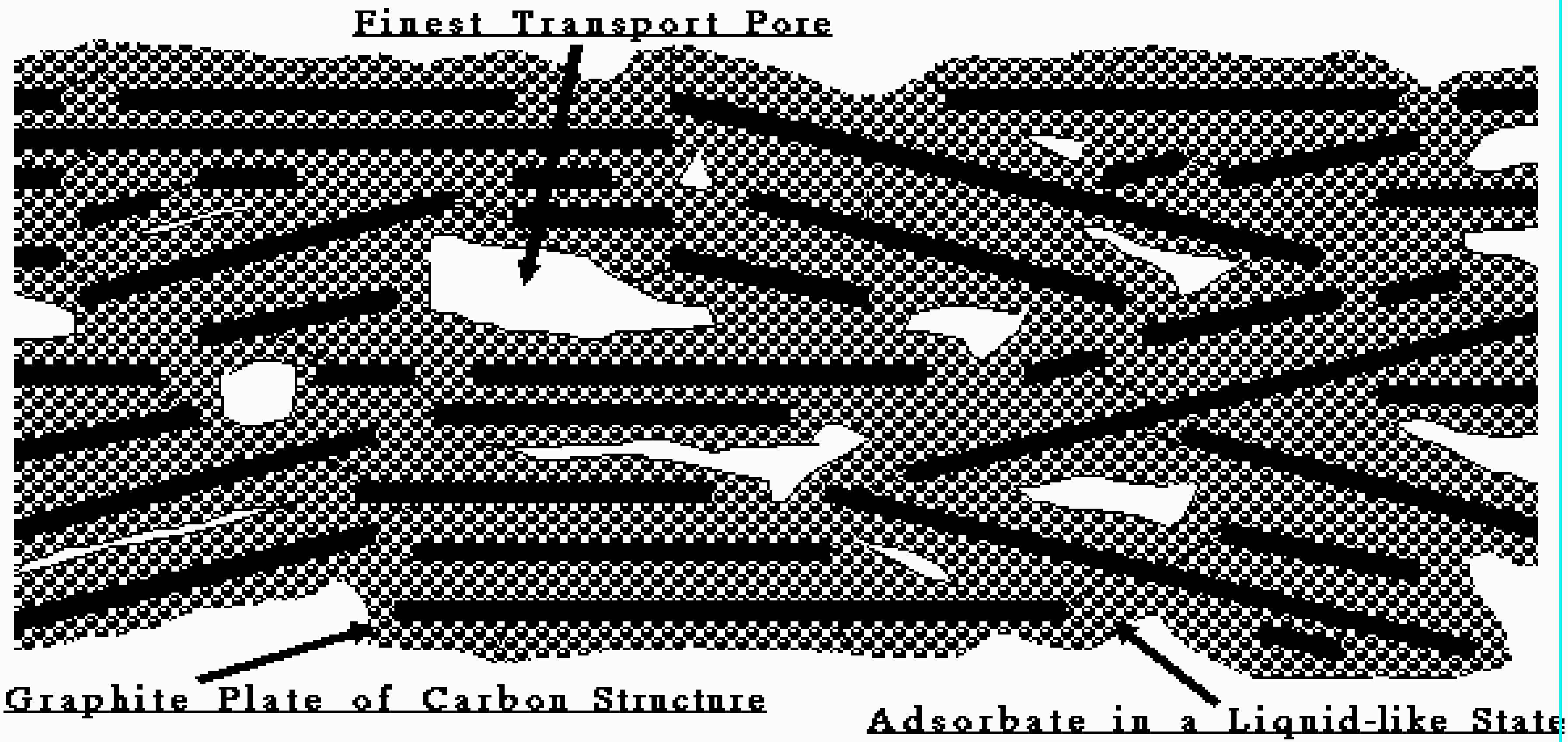
Molecular Structure of Activated Carbon



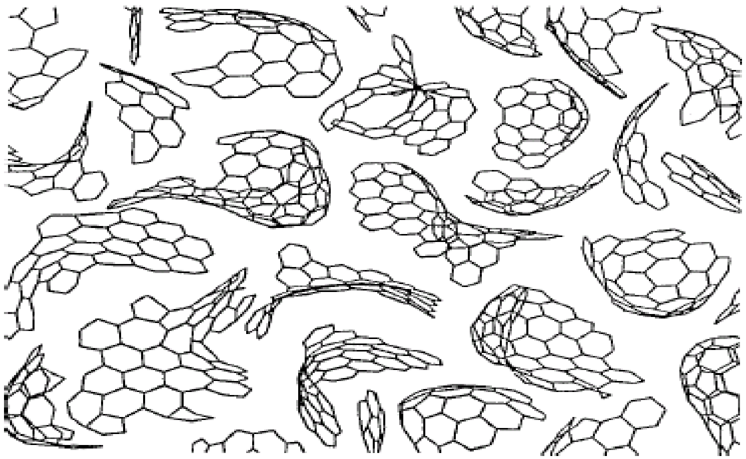


Loaded Activated Carbon

10,000,000 X magnification



Amorphous Graphite = Domains of Graphene



208 INTERDISCIPLINARY SCIENCE REVIEWS, 2001, VOL. 26, NO. 3

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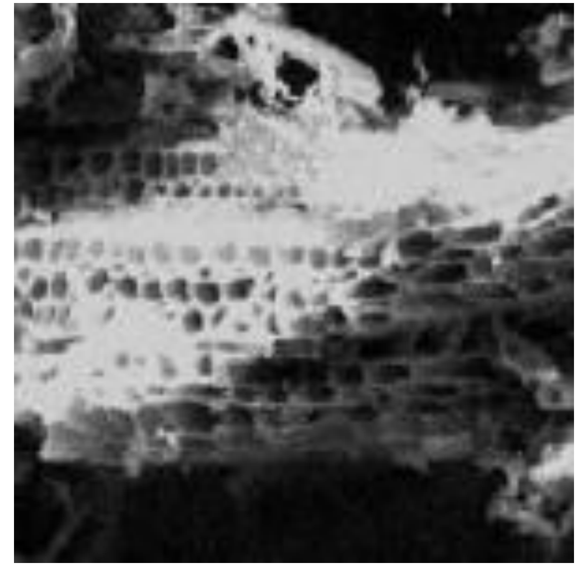


According to the **IUPAC** International Union of Pure and Applied Chemistry), three groups of pores are distinguished, according to the **pore size**:

International Union of Pure and Applied Chemistry

- Macropores (> 50 nm diameter)
- Mesopores (2-50 nm diameter)
- Micropores (< 2 nm diameter)

Micropores generally contribute to the major part of the internal surface area. **Macro and mesopores** can generally be regarded as the highways into the carbon particle, and are crucial for kinetics in and out of the micropores.

Most bacteria are 0.2 µm in diameter and 2-8 µm in length.

In the Soil: (µm = micro-meter = 10^{-6} meter)

Macropore: These pores are full of air. Size >75 µm.
Mesopore: storage pores for water,. Size 75 µm–30 µm.
Micropore: The pores that are filled with water and is important to the activity of microbes. Size <30 µm.

In the Biochar: (nm = nano-meter = 10^{-9} meter)

Macropores (> 50 nm diameter)
Mesopores (2-50 nm diameter)
Micropores (< 2 nm diameter)

We note: 1 µm = 1000 nm

So, in size and especially volume, *Soil pores >>> Biochar pores*

So, Biochar actually adds a new functionality to the soil matrix due to the increase in adsorption

-Traditional soil pores are involved with the storage of soil water, as measured by the “field capacity”. They also serve as large reservoirs of liquid that are inhabited by soil microbes. The smallest soil pores are still large enough for occupancy by most soil microbes.

-Biochar pores include very small pores, which have internal walls of attractive graphite that provide sites for the adsorption of organic chemicals in soil water, including beneficial soluble SOM and toxic organics that inhibit soil microbes and impact plant health, such as allelochemicals and glyphosate (Roundup….).

So, Biochar actually adds a new functionality to the soil matrix due to the increase in adsorption

- Biochar also includes pores that bracket the range of individual soil microbe sizes, providing protective habitat and stabilizing soil conditions to allow higher rates of microbe survival during drought conditions and between periods of active crop growth.

- Adding ¼ inch of biochar to the soil, and working it into the root zone (or waiting for Mother Nature to do it for you), is the same as adding over 100,000 sheets of graphite – all of it composed of surfaces that bind organic chemicals and water vapor, then release them back into the soil when they are needed by the plants and soil microbes.

Options for obtaining Biochar

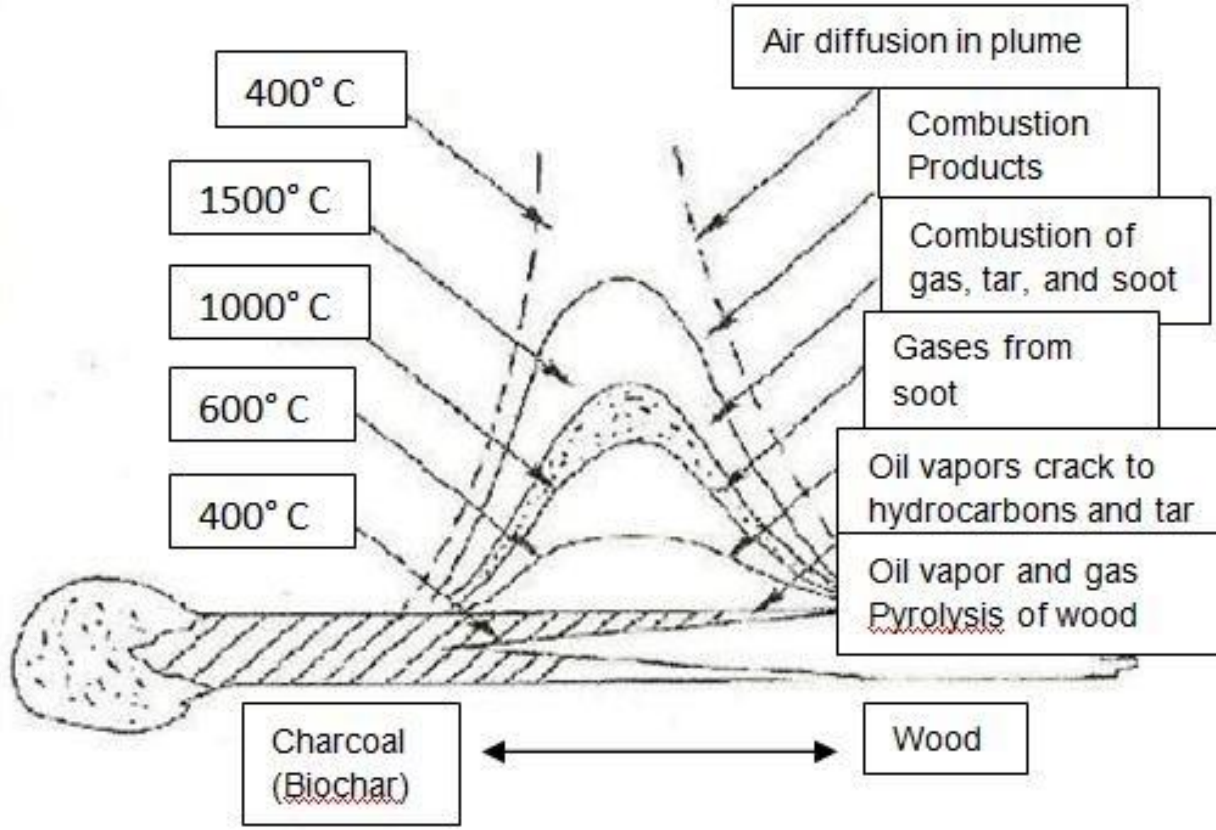
- You can **make it**
  - For "gardening", TLUDs work best
  - The other approach is "Retort" processes
  - Equipment is coming to the market – slowly
    - Example: Flame Curtain devices & Troughs
- You can **buy it** – more on that later
- You can **steal it** – definitely the best way – less work, faster, safer, ***frowned upon by the law***……

How Biochar is made

- From any plant matter
- Using one simple tool – Fire (actually heat)
- Yield, quality and effort depend on device
- One important distinction between Chars:
  - **Charcoal is a fuel**, burns without smoke and very hot, used for cooking and metal refining
  - **Biochar is a soil amendment**, and is valued by its impact and effectiveness in growing systems

How does wood burn?

- Wood, consists of hemicellulose, cellulose and lignin
  - Hemicellulose gasifies at 250 – 300C
  - Cellulose splits into char and volatiles between 300C and 450C
  - Lignin splits into char and volatiles between 300C and 750C
  - Volatilization cools the remaining solid, but the gases burn and generate radiant heat (yellow to blue light)
  - Eventually, oxygen can react with the remaining char to make CO_2, H_2O and ash, plus more heat (red light)
  - **Putting it all together, we have:**

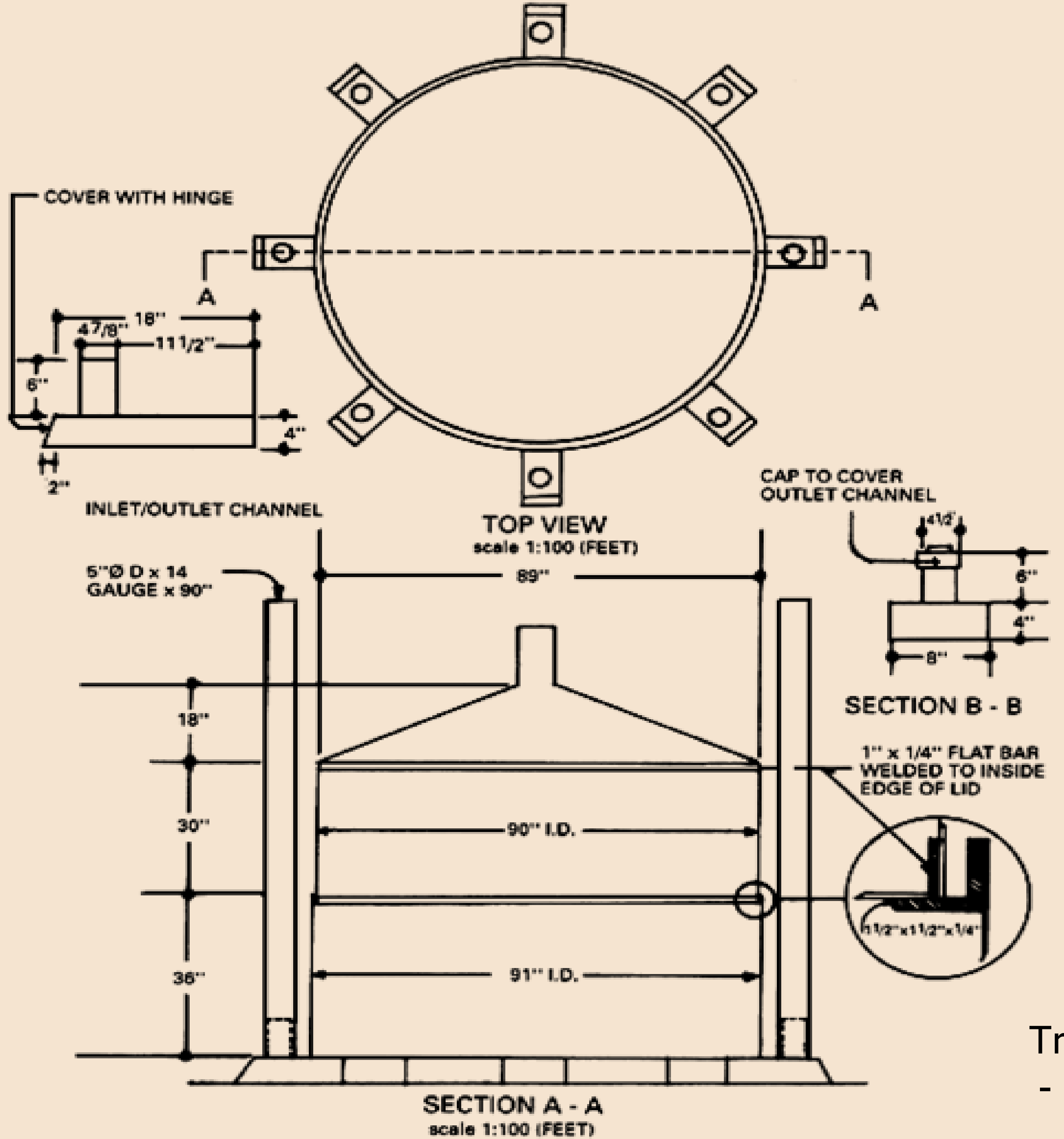


Air diffusion in plume
400° C
Combustion Products
1500° C
Combustion of gas, tar, and soot
1000° C
Gases from soot
600° C
Oil vapors crack to hydrocarbons and tar
400° C
Oil vapor and gas
Pyrolysis of wood
Charcoal (Biochar)
Wood

Any Volunteers for running a Earth mound Kiln?

Charcoal burners were a strange breed, living a lonely life in the forest, like wild beasts… *At its best, making charcoal was not for any normal human. The time required for charring a small mound varied from one to two weeks, but with mounds 30 feet or more round, a month was average. During all that time, through every kind of weather, the charcoal maker lived with his mound, sleeping only in dozes for fear a flame might start and explode into a full fire which would demolish the mound. There was no time for washing; there was seldom more shelter than a bark lean-to.*

Earth Kiln – Ohio - 1942



Tropical Products Institute
 - Mark V

Tropical Products Institute
- Mark V – IN ACTION

Search: **double barrel twin keg biochar**

Search:

Jolly Roger Ovens

or

55-gal TLUD

Options for purchasing Biochar

- If you have a credit card, the world just can’t wait to deliver **THEIR biochar to YOU**
- Amazon.com: **232 results for “biochar”**
- Working on a 2017 NOFA bulk order offering
- www.NextChar.com – “Buy Now” button
- Bulk products at martinsfarmcompost.com
- Also citysoil.org @ boston-compost-site

methods for integrating biochar into a variety of organic growing systems

- ***Biochar works in conjunction with the existing soil, crop and climate.***
- ***Biochar helps "soil" go back to being soil.***
- ***Anytime you visit the soil, look for opportunities to introduce biochar into the ongoing growing system***

Freshly made Biochar is like raw Ground Beef
- is it food? – not just yet ……

Considerations for preparing biochar for optimal soil benefits

- **Conditioning:** equilibrate with soil moisture properties
    - pH effects, total dissolved solids (salts), liming
    - desorb soluble sugars and other mobile matter
- **Charging:** equilibrate with soil fertilizer levels
    - in balance with annual fertilizer fluxes (bio-rhythms?)
- **Stabilizing SOM:** Cycling SOM into soil microbe "plasms"
    - soluble nutrients are incorporated into living tissue
    - soil leaching is reduced and soil resources are conserved
    - soil carbon reservoirs are created, building soil complexity

All of which happens during composting or given enough time

How to introduce Biochar into existing growing systems:

At NextChar.com – Resources – a “whitepaper” titled
Methods for integrating Biochar in existing growing systems
by Hugh McLaughlin, PhD, PE – CTO – NextChar.com

1) Think about **Conditioning-Charging-Stabilizing SOM** – have these three steps been allowed to happen before the plant needs to interact with the biochar-amended soil beneficially.

1) Biochar works at different levels depending on what it is changing: very low levels for detoxification and up to 10 volume percent to correct soil physical defects related to water retention and inadequate soil aeration. Adding some each year is a strategy for realizing incremental benefit and knowing when is enough.

How to introduce Biochar into existing growing systems:

3) **Introduce the raw biochar to a growing crop soil slowly over either time or space** – put it in before the period of rapid plant growth or top-dress the biochar and let it work into the soil over the growing season.

4) Look at events when you interact with the soil and identify opportunities to introduce biochar into the soil matrix.

   * If it doesn't blow or wash away, it will get where it is needed

5) Biochar and Compost are really a perfect combination:

   * Raw biochar into the front end of the composting process makes the biological process of composting proceed better and faster

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Time for Questions, Clarifications and Audience Observations

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